Vehicle Routing Problem Using Sweep Algorithm for Determining Distribution Routes on Blood Transfusion Unit

by Fitra Lestari

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Abstract

This case study investigated blood distribution on a Blood Transfusion Unit at the Red Cross in Indonesia. This unit facilitates health services in organizing blood donations, blood examinations, and blood distribution for patients. Currently, the management of blood distribution from the Blood Transfusion Unit to the hospital does not consider the optimal distance and route of blood distribution. In addition, this case study shows that 19 hospitals request types of blood to the Blood Transfusion Units. This study aims to determine the optimal route of blood distribution in the Blood Transfusion Unit. This study needs to solve the Vehicle Routing Problem by adopting the Sweep Algorithm to minimize the distance of blood distribution and determine the distribution route. Optimization of blood distribution found a reduction in the distance by 57% with a reduction in time of 58%. Further research is suggested to determine the scheduling of ordering blood requirements to obtain optimal results.

Keywords
Sweep Algorithm, Blood Distribution, Vehicle Routing Problem, Blood Transfusion Unit, Hospital.

1. Introduction

Currently, blood bank facility has become a regional issue to meet human health needs. Distributing the blood supply is an important factor in the health system because blood is an important human body component. One of the characteristics of blood is that it is a commodity product easily damaged or not durable (Aritonang et al., 2012). Thus, it needs to be managed and monitored with strict regulations for use by patients. In addition, Ghartimagar (2017) revealed that the distribution of blood products must be managed properly to be used in the right amount and time. Blood supply activity in Indonesia is carried out by the Indonesian Red Cross Society, where this organization is engaged in social humanity and is recognized nationally and internationally. Puspasari (2017) stated that the Indonesian Red Cross Society carries out its duties on the humanitarian mission always to be sensitive, responsive, and active to meet the needs of the general public. The Indonesian Red Cross Society provides a Blood Transfusion Unit (BTU) to provide services to the community to provide blood components for those in need. The activities of the Blood Transfusion Unit are in the form of facilitating or providing services in organizing blood donations, providing blood, and distributing blood with the aim of healing disease and restoring health (Lestari *et al*., 2017)**.**

This research was conducted at the Blood Transfusion Unit in Pekanbaru, Indonesia. The unit serves various blood examination transactions and distributes blood to hospitals or hospital Blood banks. The need for blood in Pekanbaru for a year in 2018 is increasing for blood transfusions to patients' which can be seen in Figure 1. High blood demand requires an optimal blood distribution system to maximize blood quality. Blood distribution is carried out through the Hospital Blood Bank (BDRS), one of the hospital service units responsible for the availability of safe, high quality, and sufficient blood. For maintaining blood quality, blood distribution from the Blood Transfusion Unit to the hospital is carried out through the Hospital Blood Bank until patients with a closed distribution system receive it. Blood Transfusion Unit officers and hospital staff carry out the distribution system without involving patients in more detail.

In addition, the blood distribution system is also carried out by considering the distribution system using cooling facilities in the form of a refrigerator and distribution system for blood products in the right temperature and condition from the point where the donor's blood is collected until the blood is transfused to the patient. The storage area for blood components is managed with certain temperature standards based on the optimal temperature level for each blood component (Efe *et al*., 2010). The treatment of blood components at the time of delivery using a transportation fleet from the storage and maintenance area needs to be considered properly in the form of a cool box storage facility. Therefore, an optimal distribution management system and route determination are needed to manage blood components in the patient.

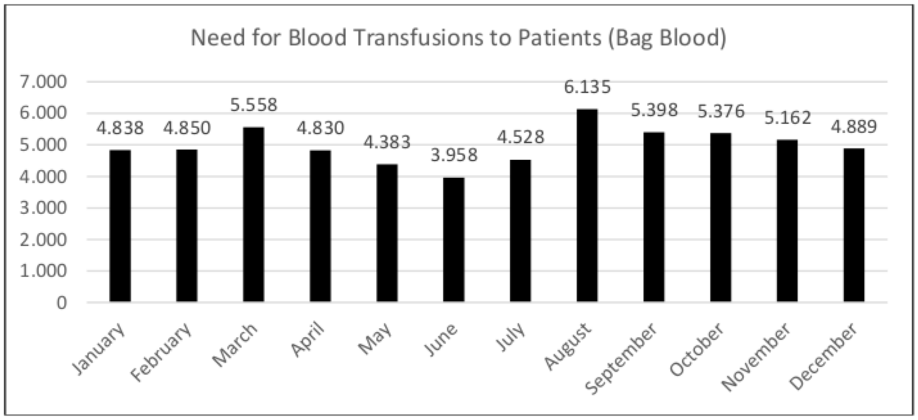

Figure 1. Need for Blood Transfusions to Patients

1.1 Objectives

This study aims to discuss the problem solving of determining the optimal blood distribution route and minimizing the distance and time by involving constraints according to the need for blood. The limitation of the problem used in this study in the form of data used is data on demand for blood distribution for one year. Then, the implementation of this study was carried out at a hospital in Pekanbaru. This study focuses on blood needs and does not focus on discussing blood specifications at the Blood Transfusion Unit in Pekanbaru, Indonesia.

2. Vehicle Routing Problem

Some researchers stated that distribution management is the setting of activity to transform products from suppliers to consumers (Affran and Asare, 2019; Chesesio and Nambuswa Makokha, 2016). The distribution route that is traversed has to be considered in distributing the products from suppliers to consumers. Therefore, the determination of blood distribution routes in this study is very important to help blood transfusion units and hospitals in providing blood to patients. It needs to be done to solve the problem of the complexity of blood distribution. Blood distribution is not carried out quickly and accurately will affect the distance traveled and the formation of distribution routes. Ideally, the business process of the Blood Transfusion Unit has an optimal blood distribution route with minimal distance and distribution time. Several studies have adopted the Sweep Algorithm to solving the Vehicle Routing Problem (VRP) in order to determine the optimal distribution route. This approach is related to determining distribution routes and grouping areas with the closest distance (Hanafi et al., 2020; Nurcahyo et al., 2002). This study needs to determine the route of blood distribution from BTU to various hospitals in Pekanbaru to serve the blood needs of patients. Therefore, an optimal problem-solving method is needed to overcome blood distributions at BTU in Pekanbaru. Problem-solving in this study was carried out by determining the Vehicle Routing Problem (VRP) to optimize blood distribution routes involving several vehicles and paying attention to obstacles to serving hospitals with their respective requests. Then, this solution adopts the Sweep Algorithm approach, an algorithm with two phases of completion, namely by clustering and forming a route for each cluster using the nearest neighbor method (Ari Santosa *et al*., 2019; Kurnia *et al*., 2020).

3. Methods

This research is a case study at the Blood Transfusion Unit in Pekanbaru, Indonesia. Primary data was collected through an interview at the blood distribution department to determine the blood distribution and blood demand activities. Furthermore, observations were made on the activities of the Blood Transfusion Unit to determine the location of the blood distribution routes at 19 hospitals in Pekanbaru. Then, secondary data includes the number of delivery vehicles, the number of blood banks, the location of the blood banks, the distance the blood bank travels to the Blood Transfusion Unit, the delivery capacity, the capacity of the blood bank, the number of blood bank requests and the number of requests for blood collected during one year. The vehicle data in this study were conducted through an interview about the type of vehicles used and the maximum transport capacity. The Pekanbaru UTD type is the Daihatsu Grand Max vehicle, which can transport two (2) cool boxes with 100 blood bags each. Determination of blood distribution policy is proposed with a vehicle routing problem (VRP) model using a sweep algorithm. The data processing steps are carried out in two ways, including:

3.1 Google maps app

The Google maps application helps solve problems regarding the agent's location, determine the coordinates, and know the travel time. Figure 2 is the step in data processing using Google maps.

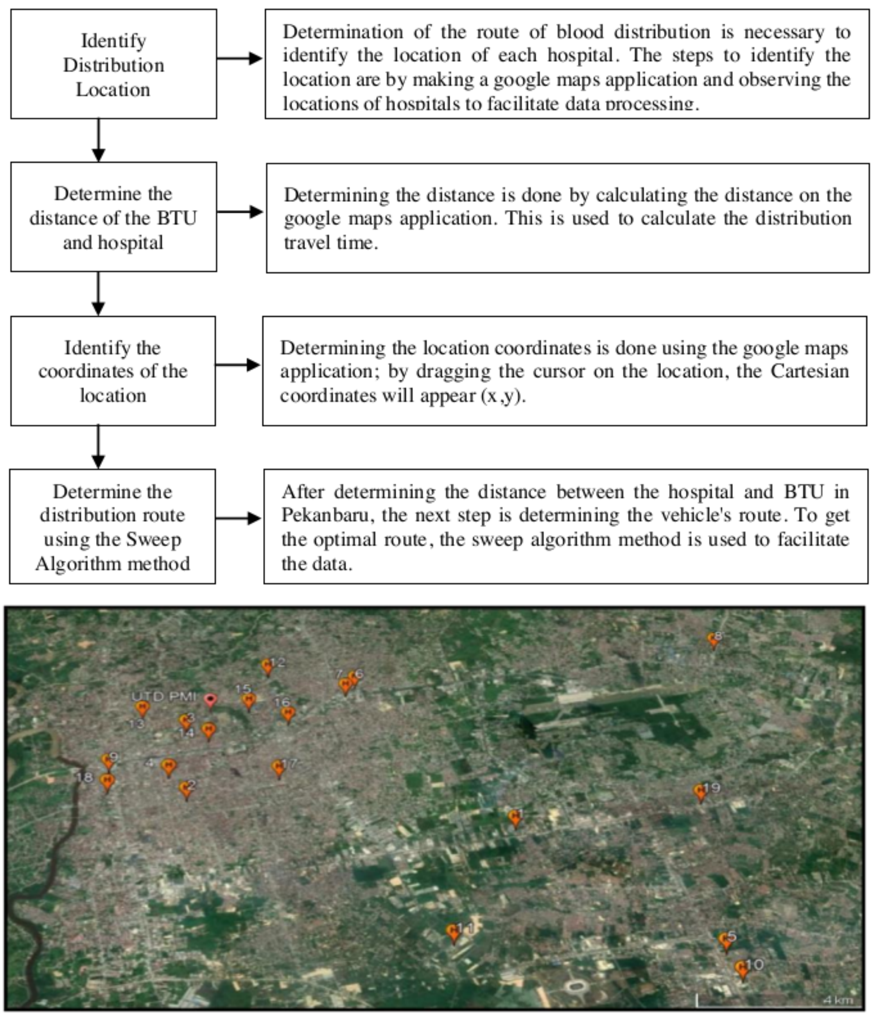

Figure 2. Google Maps App

3.2 Sweep algorithm

Determination of the optimal route of blood distribution is implemented by making the trip's starting point on the sweep algorithm method a blood transfusion unit Pekanbaru for distributing blood to blood banks (hospitals). Figure 3 shows the use of the sweep algorithm method.

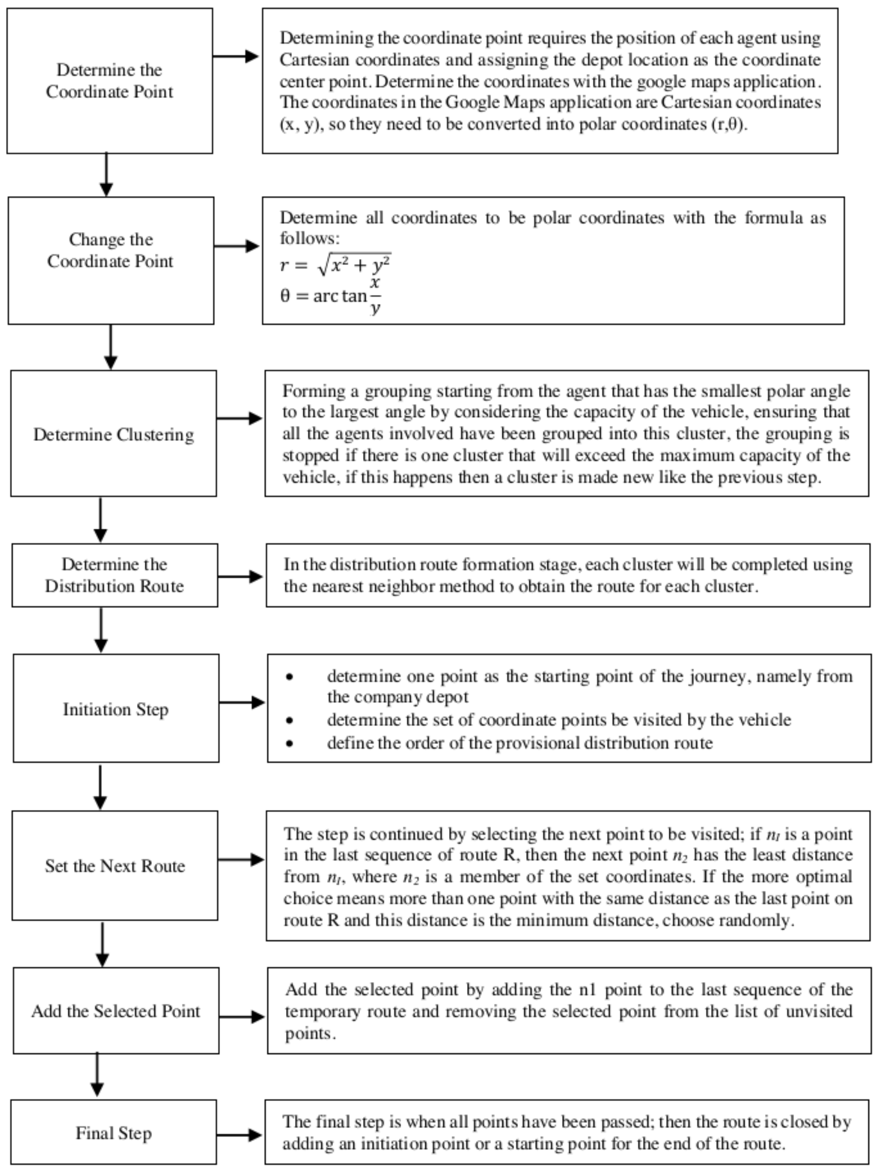

Figure 3. the sweep algorithm

4. Results and Discussion

The initial step is to determine the location points of 19 hospitals in Pekanbaru, determined based on Latitude (X) and Longitude (Y). Then, this step is continued to determine the distance between each hospital and the Blood Transfusion Unit in Pekanbaru. The Depot (BTU) location is used as the coordinate center to determine the polar coordinates for each hospital in Pekanbaru. Then, Polar coordinate order is carried out from the smallest to the largest. Petala Bumi Hospital is the smallest polar coordinate point. Angle determination is done using the help of the google maps application and processed using the google earth application. Table 1 shows the polar coordinate sequence for 19 hospitals in Pekanbaru and blood needs per bag for a year in 2018. Clustering can be divided into one delivery group because the vehicle capacity still has free space to transport the demand for blood bags at each hospital. The number of blood bags sent to all hospitals in Pekanbaru is an average of 150 bags. Then, the distance and travel time between hospital locations in Pekanbaru were determined. The determination of the distance matrix and time matrix can be seen in table 2 and table 3.

Table 1. The polar coordinate and blood needs for 19 hospitals in Pekanbaru

Hospital Code	Hospital	Distance (km)	Latitude (X)	Longitude (Y)	(θ^o)	Requirement of Blood/Year (Bag)
H13	Petala Bumi Regional Public Hospital	3.5	0.496589	101.4563	6	4146
H12	PMC Hospital	0.95	0.520334	101.4490	147	428
H6	Awal Bros Sudirman Hospital	8	0.49662	101.4003	181	230
H8	Mesra Hospital	2.9	0.525642	101.4368	182	2895
H7	Syafira Mother And Child Hospital	12	0.463205	101.3903	185	2277
H15	Zainab Mother And Child Hospital	0.9	0.523593	101.4518	196	28667
H16	Tabrani Hospital	3.1	0.5119	101.4382	209	1283
H19	Sansani Mother And Child Hospital	4.3	0.498371	101.4549	210	2918
H1	Eka Hospital	1.3	0.513846	101.4548	225	549
H10	Aulia Hospital	11	0.45528	101.4188	231	870
H5	Awal Bros Panam Hospital	13	0.463256	101.3852	232	173
H17	Eria Bunda Mother And Child Hospital	2.7	0.527134	101.4422	248	3400
H11	Prima Hospital	10	0.439631	101.4524	248	125
H14	Riau Police Department Hospital	2.5	0.508901	101.4623	281	587
H2	Ibnu Sina Islamic Hospital	7.9	0.482362	101.42	291	4015
H4	Santa Maria Hospital	10	0.536443	101.4412	299	170
H3	Arifin Achmad Regional Public Hospital	1.5	0.529044	101.4569	313	900
H18	Army Hospital	3.3	0.535063	101.4452	320	699
H9	Bina Kasih Hospital	2.7	0.508151	101.45	326	377

Table 2. distance matrix (km)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
0		5.73	2.28	0.67	1.8	9.58	2.48	2.28	8.78	2.19	10.04	6.69	1.31	1.13	0.81	0.64	1.36	2.14	2.56	8.19
1	5.73		5.16	5.78	5.58	3.9	4.37	4.29	5.96	6.56	4.41	2.69	5.59	6.61	5.33	5.19	4.44	3.88	6.44	3.99
2	2.28	5.16		1.71	0.64	8.64	3.89	3.63	9.67	1.47	9.01	5.18	3.41	2.25	1.49	2.42	2.43	1.52	1.28	8.04
3	0.67	5.78	1.71		4.17	9.56	3	2.77	9.25	1.53	9.99	6.46	1.98	0.84	0.45	1.41	1.67	1.97	1.88	8.38
4	1.8	5.58	0.64	4.17		9.17	3.73	3.48	9.76	0.99	9.55	5.78	3.02	1.61	1.06	2.07	2.28	1.75	1.01	8.39
5	9.58	3.9	8.64	9.56	9.17		8.26	8.17	7.37	10.11	0.58	3.88	9.49	10.38	9.1	9.06	8.32	7.59	9.89	3.27
6	2.48	4.37	3.89	3	3.73	8.26		0.26	6.31	4.48	8.76	6.24	1.52	3.6	2.76	1.86	1.47	2.65	4.72	6.45
7	2.28	4.29	3.63	2.77	3.48	8.17	0.26		6.5	4.24	8.69	6.08	1.44	3.41	2.52	1.66	1.22	2.39	4.47	6.24
8	8.78	5.96	9.67	9.25	9.76	7.37	6.31	6.5		10.66	7.95	8.6	7.75	9.93	8.97	8.17	7.62	8.18	10.79	4.16
9	2.19	6.56	1.47	1.53	0.99	10.11	4.48	4.24	10.66		10.48	6.63	3.49	1.43	1.72	2.66	3.06	2.73	0.51	9.38
10	10.04	4.41	9.01	9.99	9.55	0.58	8.76	8.69	7.95	10.48		4.1	9.99	10.81	9.53	9.53	8.8	8.02	10.24	3.84
11	6.69	2.69	5.18	6.46	5.78	3.38	6.24	6.08	8.6	6.63	4.1		7.04	7.23	6.04	6.34	5.69	4.55	6.32	5.02
12	1.31	5.59	3.41	1.98	3.02	9.49	1.52	1.44	7.75	3.49	9.99	7.04		2.33	1.97	0.99	1.38	2.72	3.86	7.67
13	1.13	6.61	2.25	0.84	1.61	10.38	3.6	3.41	9.93	1.43	10.81	7.23	2.33		1.29	1.77	2.43	2.8	1.91	9.21
14	0.81	5.33	1.49	0.45	1.06	9.1	2.76	2.52	8.97	1.72	9.53	6.04	1.97	1.29		1.01	1.35	1.53	1.97	7.96
15	0.64	5.19	2.42	1.41	2.07	9.06	1.86	1.66	8.17	2.66	9.53	6.34	0.99	1.77	1.01		0.79	1.84	2.96	7.58
16	1.36	4.44	2.43	1.67	2.28	8.32	1.47	1.22	7.62	3.06	8.8	5.69	1.38	2.43	1.35	0.79		1.39	3.24	6.85
17	2.14	3.88	1.52	1.97	1.75	7.59	2.65	2.39	8.18	2.73	8.02	4.55	2.72	2.8	1.53	1.84	1.39		2.74	6.65
18	2.56	6.44	1.28	1.88	1.01	9.89	4.72	4.47	10.79	0.51	10.24	6.32	3.86	1.91	1.97	2.96	3.24	2.74		9.36
19	8.19	3.99	8.04	8.38	8.39	3.27	6.45	6.24	4.16	9.38	3.84	5.02	7.67	9.21	7.96	7.58	6.85	6.65	9.36	

Table 3. Time matrix (minute)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
0		6.88	2.74	0.80	2.16	11.50	2.98	2.74	10.54	2.63	12.05	8.03	1.57	1.36	0.97	0.77	1.63	2.57	3.07	9.83
1	6.88		6.19	6.94	6.70	4.68	5.24	5.15	7.15	7.87	5.29	3.23	6.71	7.93	6.40	6.23	5.33	4.66	7.73	4.79
2	2.74	6.19		2.05	0.77	10.37	4.67	4.36	11.60	1.76	10.81	6.22	4.09	2.70	1.79	2.90	2.92	1.82	1.54	9.65
3	0.80	6.94	2.05		5.00	11.47	3.60	3.32	11.10	1.84	11.99	7.75	2.38	1.01	0.54	1.69	2.00	2.36	2.26	10.06
4	2.16	6.70	0.77	5.00		11.00	4.48	4.18	11.71	1.19	11.46	6.94	3.62	1.93	1.27	2.48	2.74	2.10	1.21	10.07
5	11.50	4.68	10.37	11.47	11.00		9.91	9.80	8.84	12.13	0.70	4.66	11.39	12.46	10.92	10.87	9.98	9.11	11.87	3.92
6	2.98	5.24	4.67	3.60	4.48	9.91		0.31	7.57	5.38	10.51	7.49	1.82	4.32	3.31	2.23	1.76	3.18	5.66	7.74
7	2.74	5.15	4.36	3.32	4.18	9.80	0.31		7.80	5.09	10.43	7.30	1.73	4.09	3.02	1.99	1.46	2.87	5.36	7.49
8	10.54	7.15	11.60	11.10	11.71	8.84	7.57	7.80		12.79	9.54	10.32	9.30	11.92	10.76	9.80	9.14	9.82	12.95	4.99
9	2.63	7.87	1.76	1.84	1.19	12.13	5.38	5.09	12.79		12.58	7.96	4.19	1.72	2.06	3.19	3.67	3.28	0.61	11.26
10	12.05	5.29	10.81	11.99	11.46	0.70	10.51	10.43	9.54	12.58		4.92	11.99	12.97	11.44	11.44	10.56	9.62	12.29	4.61
11	8.03	3.23	6.22	7.75	6.94	4.06	7.49	7.30	10.32	7.96	4.92		8.45	8.68	7.25	7.61	6.83	5.46	7.58	6.02
12	1.57	6.71	4.09	2.38	3.62	11.39	1.82	1.73	9.30	4.19	11.99	8.45		2.80	2.36	1.19	1.66	3.26	4.63	9.20
13	1.36	7.93	2.70	1.01	1.93	12.46	4.32	4.09	11.92	1.72	12.97	8.68	2.80		1.55	2.12	2.92	3.36	2.29	11.05
14	0.97	6.40	1.79	0.54	1.27	10.92	3.31	3.02	10.76	2.06	11.44	7.25	2.36	1.55		1.21	1.62	1.84	2.36	9.55
15	0.77	6.23	2.90	1.69	2.48	10.87	2.23	1.99	9.80	3.19	11.44	7.61	1.19	2.12	1.21		0.95	2.21	3.55	9.10
16	1.63	5.33	2.92	2.00	2.74	9.98	1.76	1.46	9.14	3.67	10.56	6.83	1.66	2.92	1.62	0.95		1.67	3.89	8.22
17	2.57	4.66	1.82	2.36	2.10	9.11	3.18	2.87	9.82	3.28	9.62	5.46	3.26	3.36	1.84	2.21	1.67		3.29	7.98
18	3.07	7.73	1.54	2.26	1.21	11.87	5.66	5.36	12.95	0.61	12.29	7.58	4.63	2.29	2.36	3.55	3.89	3.29		11.23
19	9.83	4.79	9.65	10.06	10.07	3.92	7.74	7.49	4.99	11.26	4.61	6.02	9.20	11.05	9.55	9.10	8.22	7.98	11.23	

Formation of the blood distribution routes using the nearest neighbor algorithm on the sweep algorithm to obtain more optimal route results and shorter travel distances and times. Several assumptions in determining the distribution route include vehicle speed is 50km/hour, traffic flow without obstacles, and using a two-way track. The route determination approach is made by selecting the starting point and finding the hospital location with the shortest distance from the starting point location. This step was carried out until 19 hospital routes were formed in this case study. Figure 4 shows the last route from the 8th hospital to the starting point (blood transfusion unit in Pekanbaru).

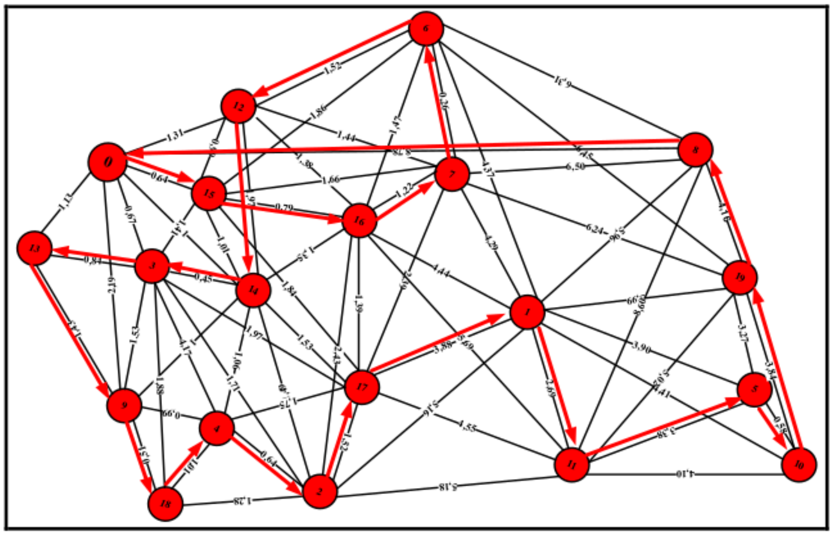

Figure 4. The last route to the starting point (BTU)

Then, a recapitulation of the blood distribution route in Pekanbaru was carried out. Figure 5 is the initial route for Blood Distribution from UTD Pekanbaru to 19 hospitals. Then, Figure 6 is the proposed route of improvement.

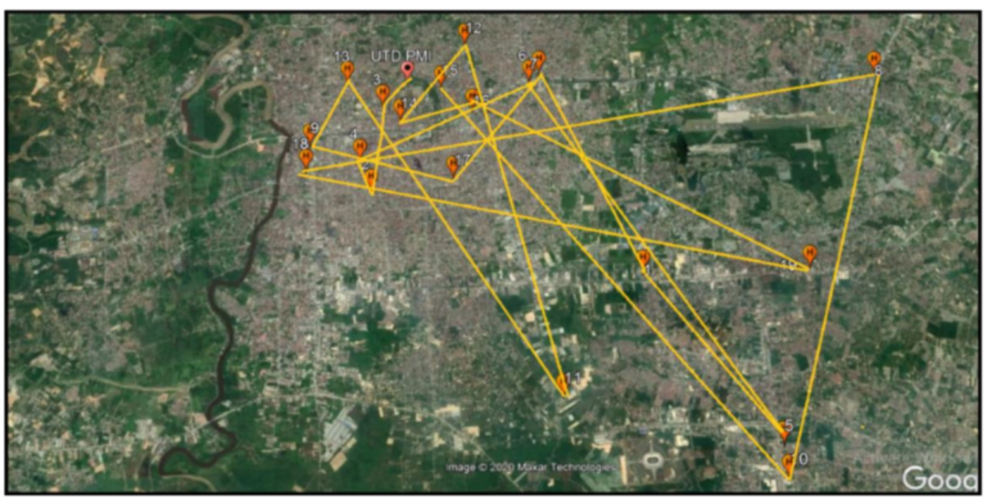

Figure 5. The initial route for Blood Distribution

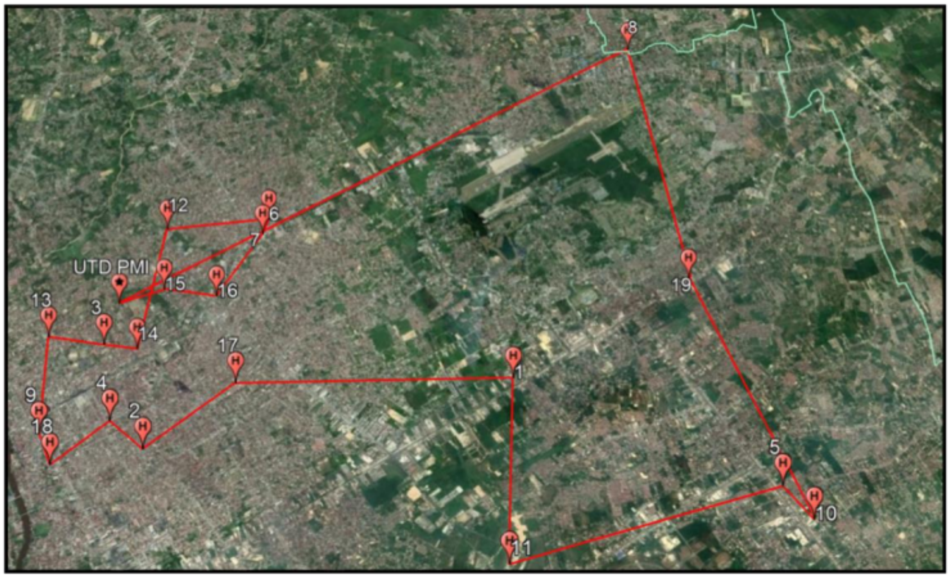

Figure 6. The proposed route of improvement for Blood Distribution

Comparison of the initial route and the proposed route has a very big difference. The initial route looks more complicated than and the track distance is longer. Meanwhile, the repair distance trajectory looks better and has an optimal trajectory. The difference in distance between the initial route and the repair route is 52.35 km. Thus, optimization of blood distribution found a reduction in the distance by 57% with a reduction in time of 58%. The comparison of the initial route and the proposed route can be seen in Table 4.

Table 4. Comparison of the initial route and the suggested route for Blood Distribution

Distribution Route	Trip (Hospital Code)	Total Distance (km)	Total Travel Time (Minute)
Initial Route	BTU-H3-H2-H4-H6-H5-H1-H7-H17-H9-H13-H11-H12-H14-H16-H19-H18-H8-H10-H15-BTU	92.46	115.84
Proposed Route	BTU-H15-H16-H7-H6-H12-H14-H3-H13-H9-H18-H4-H2-H17-H1-H11-H5-H10-H19-H8-BTU	40.11	48.13

Determination of blood distribution routes at the blood transfusion unit in Pekanbaru has obtained the significant result of the research as optimal route determination. Implementing the suggested route is carried out using the Sweep Algorithm method with a good level of accuracy to solve non-optimal blood distribution routes. There is 50% above reduction in distance and time on the proposed route improvements in this case study. (Peya *et al*., 2019) also implements the Sweep method in his research. The result is the formation of proposed households that can assist the production process. Furthermore, the initial conditions of the blood distribution route in the blood transfusion unit to the hospital in Pekanbaru were analyzed based on the demand for blood counts in each hospital. Thus, this route for distributing blood was carried out irregularly. This results in a longer route of blood distribution take a long time and can allow for reduced quality of blood components. The route for improving the blood distribution in the Pekanbaru blood transfusion unit is carried out using the Sweep Algorithm method, taking into account capacity and distance. This study obtained a good and optimal distribution route so that the delivery time is relatively short; the distance is more regular than, and the quality of the blood is also very protected. The determination of distribution routes is influenced by fluctuations in the number of product requests so that the routes follow the conditions that occur. (Meng *et al*., 2019) stated that the suggested distribution route improvement is not constant because it is influenced by consumer demand. Thus, there will be a change in the route due to a change in demand.

Determination of blood distribution routes also takes into account the traffic flow in Pekanbaru. In addition, it also considers the speed and capacity of blood-carrying vehicles. This assumption affects the distribution of blood to be delivered to consumers smoothly and optimally. Thus, the number of requests and confirmation from the hospital makes the distribution of blood even better. (Li *et al*., 2019) stated that real-time data and demand certainty affect product distribution policies.

5. Conclusion

This study shows the significant result of the research for the implementation of the sweep algorithm method in the vehicle routing problem. The finding is able to optimize blood distribution routes by minimizing the distance and the time of blood distribution. This study also provides benefits for maintaining the quality of blood transfused to blood recipients because optimizing blood distribution can improve blood quality and the safety of donor recipients. Blood distribution requires real-time blood demand information. Thus, this study is recommended to be integrated with the blood demand information system at each hospital to get the accuracy of blood demand for each period.

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